

10-30-00

A

Patent
245/090

To: Box Patent Application
Commissioner for Patents
Washington, D.C. 20231

NEW APPLICATION TRANSMITTAL - UTILITY

Sir:

Transmitted herewith for filing is a **utility** patent application:

Inventor(s): Gregory G. Davis, Richard C. Stribling,
Randy L. Engle and Richard M. Nelhams

Title: DUAL MODE UPLINK/DOWNLINK LOCATION MEASUREMENT
AND MULTI-PROTOCOL LOCATION MEASUREMENT

I. PAPERS ENCLOSED HEREWITH FOR FILING UNDER 37 CFR § 1.53(b):

- 17 Page(s) of Written Description
5 Page(s) Claims
1 Page(s) Abstract
8 Sheets of Drawings ☐ Informal ☒ Formal

II. ADDITIONAL PAPERS ENCLOSED IN CONNECTION WITH THIS FILING:

- ☐ Declaration
☒ Power of Attorney ☐ Separate ☒ Combined with Declaration
☐ Assignment to _____ and assignment cover sheet
☐ Verified Statement establishing "Small Entity" under 37 CFR §§ 1.9 and 1.27
☐ Priority Document No(s):
☐ Information Disclosure Statement w/PTO 1449 ☐ Copy of Citations
☐ Preliminary Amendment
☒ Return Postcard

WP-10122.1

CERTIFICATE OF MAILING
(37 C.F.R. §1.10)

I hereby certify that this paper (along with any referred to as being attached or enclosed) is being deposited with the United States Postal Service on the date shown below with sufficient postage as 'Express Mail Post Office To Addressee' in an envelope addressed to the Commissioner for Patents, Washington, D.C. 20231.

EL616997832US

Express Mail Label No.

October 27, 2000

Date of Deposit

Andrea Noguera

Name of Person Mailing Paper

Andrea Noguera
Signature of Person Mailing Paper

III. THE FILING FEE HAS BEEN CALCULATED AS SHOWN BELOW:

BASIC FILING FEE:						\$710.00
Total Claims	17	-	20	=	10 x \$18.00	\$0.00
Independent Claims	4	-	3	=	1 x \$80.00	\$80.00
Multiple Dependent Claims	\$270	(if applicable)			<input type="checkbox"/>	\$0.00
TOTAL OF ABOVE CALCULATIONS						\$790.00
Reduction by ½ for Filing by Small Entity. Note 37 CFR §§ 1.9, 1.27, 1.28. If applicable, Verified Statement must be attached.						\$0.00
Misc. Filing Fees (Recordation of Assignment -- \$40)						
TOTAL FEES DUE HEREWITH						\$790.00

IV. METHOD OF PAYMENT OF FEES

- ☒ A check in the amount of \$790.00.
- ☐ Charge Lyon & Lyon's Deposit Account No. **12-2475** in the amount of _____.
- ☐ This application is being filed without fee or Declaration under 37 CFR § 1.53.

V. AUTHORIZATION TO CHARGE FEES

The Commissioner is authorized to credit any overpayment and to charge any underpayment to Lyon & Lyon's Deposit Account No. **12-2475** for the following:

- ☒ 37 CFR § 1.16 – (Filing fees and excess claims fees)
- ☒ 37 CFR § 1.17 – (Any application processing fees)
- ☐ 37 CFR § 1.21 – (Assignment recording fees)

CORRESPONDENCE ADDRESS

Please send all correspondence to Customer Number 22249:



22249

PATENT TRADEMARK OFFICE


LYON & LYON LLP
Suite 4700
633 W. Fifth Street
Los Angeles, CA 90071

Please direct all inquiries to Robert S. Mayer, at 914-421-4609.

Respectfully submitted,

LYON & LYON LLP

Dated: October 27, 2000

By: 
Robert S. Mayer
Reg. No. 38,544

S P E C I F I C A T I O N

TITLE

DUAL MODE UPLINK/DOWNLINK LOCATION MEASUREMENT
AND MULTI-PROTOCOL LOCATION MEASUREMENT

5

BACKGROUND OF THE INVENTION

1. Field of the Invention

10 The field of the present invention relates to location services. More particularly, the field of the present invention relates to locating a mobile device by noting times of arrival of signals that travel between the mobile device and a plurality of transmitters or receivers located at known positions, and computing a location based on the noted times of arrival.

11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183

is then sent to a mobile location center (MLC) 19, which is a special purpose processor. The MLC 19 then uses conventional algorithms, which are well known to those skilled in the art, to determine the location of the mobile device 10 based on the TOA measurements and σ determinations made by the LMUs 15-17 and the known location of the LMUs.

One suitable conventional location algorithm uses a Taylor search to locate the intersection of two or more hyperbolas. Details of a such an algorithm can be found in "Statistical Theory of Passive Location Systems" by D.J. Torrieri, IEEE Transactions on Aerospace and Electronic Systems, Vol. AES-20, No. 2, March 1984, which is incorporated herein by reference and is an indication of the existing level of skill in the art. This algorithm locates the mobile device by finding the intersection of two or more hyperbolas determined from three or more stations. Ordinarily, this type of location algorithm is applied to three or more TOA measurements (which are used to determine the distance from the mobile device to the LMU based on the speed c of the signal), the associated σ s, and the known locations of each LMU.

FIG. 2 depicts a conventional downlink approach, where each of a plurality of base stations (BTSS) 21-23 sends a signal to the mobile device 20 to be located, and the mobile device 20 determines the TOA and σ of each of these signals. These TOA measurements and σ s are then transmitted to an MLC 29, which implements a conventional algorithm to determine the mobile device's location based

on the TOA measurements and the σ s, similar to the algorithm in the uplink type systems. Alternatively, if sufficient processing power is available in the handset 20, the algorithm may be implemented in the handset. When the transmission frames of the BTSs 21-23 are not synchronized, the downlink algorithms are somewhat more complex than the uplink algorithms because the MLC must obtain the relative time difference between each BTS transmission to calculate a location. This relative time information can be obtained using LMUs 25, 26 located at known locations to measure the TOAs of the signals from the BTSs 21-23, in a conventional manner.

One advantage of downlink location systems over uplink systems is that extra downlink handsets can be added onto a communication network without adding extra capacity to the network. Another advantage of downlink systems is that the required LMU density is lower for downlink systems, because downlink LMUs are only needed to synchronize the frames between the BTSs, and not to make TOA measurements of signals arriving from multiple handsets. But in order to implement downlink location services, TOA measurements must be made in the handset. Unfortunately, most handsets already released in the field (hereinafter "legacy handsets") cannot implement the TOA measurements required for downlink location estimation. As a result, these legacy handsets cannot be located by a downlink system. This inability to locate the vast majority of existing handsets is a major shortcoming of downlink systems.

Another shortcoming of conventional locations systems is that each conventional system only works using a single communication protocol, and cannot locate handsets that use different communication protocols. For example, a location system designed to locate TDMA handsets will not be able to locate handsets that communicate using GSM or AMPS. Because location services must be provided for all types of handsets, the conventional approach for supporting all communication protocols would involve a separate location system for each protocol, and a correspondingly expensive infrastructure.

In addition to the high monetary cost of providing a separate location service infrastructure for each of the various technologies, there may also be high costs from a community relations standpoint. Some homeowners try to block carriers' plans to install antenna towers near their homes. As a result, a carrier may have to spend upwards of \$50,000 to obtain approval for a single antenna site, and may have to wait a long time to obtain the required administrative approval. When separate infrastructures are installed for each technology, these problems may be encountered over and over with each new installation.

The inventors have recognized a need to obtain the benefits of downlink location services while avoiding the shortcomings of downlink.

The inventors have also recognized a need to provide location services for handsets that use many different communication protocols, without using a prohibitively expensive infrastructure.

SUMMARY OF THE INVENTION

Certain aspects of the present invention relate to combining uplink and downlink technologies into a single location system, to obtain the benefits offered by both of these technology and to eliminate many of their individual shortcomings. Other aspects of the present invention relate to combining location services for different communication protocols into a single system.

One aspect of the present invention is directed to a method of locating mobile devices using either uplink or downlink technology. This method includes the steps of locating a first mobile device by determining when a signal from the mobile device reaches each of at least three measurement units, and computing a location based on the times of arrival. This method also includes the steps of locating a second mobile device by determining when signals from at least three base stations reach the second mobile device, by determining when those signals reach the measurement units, and computing a location based on these determinations.

Another aspect of the present invention is directed to a method of locating a mobile device using both uplink and downlink technologies. This method includes steps of determining at least two times of arrival for uplink signals, determining at least two times of arrival for downlink signals, and computing a location of the mobile device based on these times of arrival. In certain embodiments, the uplink times are used to define first hyperbola, the downlink times are used to define a second

hyperbola, and the location is computed by finding the intersection of these hyperbolas.

Another aspect of the present invention is directed to a system for determining the location of a mobile device in either an uplink mode or a downlink mode. The system includes an uplink processor and a downlink processor, at least three base stations that communicate with the mobile device, and at least three measurement units. In the uplink mode, the measurement units determine the TOA of a signal that originated from the mobile device, and report the TOA measurements to the uplink processor. The uplink processor determines the location of the mobile device based on the TOA measurements. In the downlink mode, the mobile device determines times of arrival of signals arriving from each of the base stations and reports the determined times of arrival to the downlink processor. The measurement units collectively determine a time of arrival of signals that originated from the base stations and report those TOA measurements to the downlink processor. The downlink processor determines the location of the mobile device based on the TOA measurements reported by the mobile device and by the measurement units. Optionally, multiple communication protocols may be supported (e.g., both TDMA and GSM).

Another aspect of the present invention is directed to an apparatus for use as a part of a communication system, where the communication system includes a mobile device, a plurality of base stations, an uplink processor, and a downlink processor. The apparatus includes a receiver that

notes a TOA of a first signal arriving from the mobile device, and forwards this noted TOA to the uplink processor. The receiver also notes a TOA of a second signal arriving from the base station, and forwards this noted TOA to the downlink processor. Optionally, multiple communication protocols may be supported.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of a prior art uplink type location system.

FIG. 2 is a schematic illustration of a prior art downlink type location system.

FIG. 3 is a schematic illustration of a dual mode uplink/downlink location system in accordance with the present invention.

FIG. 4A is a schematic illustration of a first type of LMU that may be used in connection with the FIG. 3 embodiment.

FIG. 4B is a schematic illustration of the first type of LMU, modified to support multiple wireless communication protocols.

FIG. 5A is a schematic illustration of a second type of LMU that may be used in connection with the FIG. 3 embodiment.

FIG. 5B is a schematic illustration of the second type of LMU, modified to support multiple wireless communication protocols.

FIG. 6 is a schematic illustration of how data from uplink measurements and downlink measurements can be combined to form a location estimate.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

5 FIG. 3 illustrates a system in which a mobile device 30 (e.g., a cell phone) can be located using either an uplink or a downlink approach. In FIG. 3, signal flow in the uplink mode is indicated with a prefix of "U:", and signal flow in the downlink mode is indicated with a prefix of "D:". Signals may be transmitted between the various system components using any desired communications standard (including, for example, ANSI-136 TDMA, AMPS, GSM, GSM 900, DCS 1800, PDC, PCS 1900, iDEN, etc.).

15 The system relies on a set of at least three dual-purpose LMUs 35-37, which can measure the TOA of signals arriving from the mobile device 30 as well as signals arriving from the base stations 31-33. These LMUs 35-37 are preferably permanently fixed to the earth at known reference locations, but may also be temporarily fixed in position (e.g., on a truck at a known reference location). It should be noted that while only three BTSS 31-33 and three LMUs 35-37 are illustrated, a larger number of BTSS and LMUs (e.g., 7) may be used to provide improved accuracy, as will be appreciated by persons skilled in the art.

25 To locate the mobile device 30 using the uplink approach, each of the LMUs 35-37 listens for a signal from the mobile device 30 such as a random access channel (RACH) burst. When the signal from the mobile device 30 arrives,

each of the LMUs 35-37 determines the TOA of the arriving signal, together with an associated quality indicator (σ). A global positioning satellite (GPS) based time reference may be used at each LMU to synchronize each TOA measurement to a common frame of reference. Each LMU then forwards its TOA measurement and σ to a MLC 39 using a suitable communication link (e.g., a hard-wired or wireless communication link). The MLC 39 includes an uplink processor 39A that is programmed to implement a conventional uplink location algorithm. After receiving the TOA measurements (and associated σ s) from each of the LMUs 35-37, the MLC 39 implements the uplink algorithm to determine the location of the mobile device 30 based on the received TOA measurements and σ s, and the known location of the LMUs.

To locate the mobile device 30 using the downlink approach, the system has each of at least three BTSS 31-33 send a signal (e.g., a broadcast control channel (BCCH) signal) to the mobile device 30. When the signals from the BTSS 31-33 arrive, the mobile device 30 determines the TOA of the arriving signals, together with an associated quality indicator (σ) for each arriving signal. The mobile device 30 then forwards the TOA information to the MLC 39, preferably over the same wireless network being used to communicate with the mobile device 30. The MLC 39 includes a downlink processor 39B that is programmed to implement a conventional downlink location algorithm. While the uplink processor 39A and the downlink processor 39B are illustrated as two distinct blocks, they may actually be

integrated together by running different algorithms on a single processor.

In the meantime, each of the LMUs 35-37 listens for signals transmitted from the BTSs 31-33. When an LMU receives a signal from a BTS, the LMU 35-37 determines the time of arrival of the arriving signal. This type of TOA measurement, (where an LMU measures the arrival time of a signal from a BTS) is referred to herein as TOA*. Each LMU then forwards the TOA* information to the MLC 39 using a suitable communication link (e.g., a hard-wired or wireless communication link). This communication link may operate using the same protocol as the handset being located (e.g., an AMPS communication link may be used when locating an AMPS protocol handset). The TOA* measurements enable the MLC 39 to compensate for any real-time difference between the transmission frames of the various BTSs 31-33. The MLC 39 then determines the location of the mobile device 30 using the downlink algorithm based on the TOA measurements and σ s received from the mobile device 30, the TOA* measurements received from the LMUs 35-37, and the known location of the LMUs and BTSs.

FIG. 4A is a schematic illustration of a dual-mode uplink/downlink LMU 40A that may be used as any of the LMUs 35-37 in the FIG. 3 embodiment. The LMU 40A includes an antenna interface 42, which interfaces with one or more receiving antennas 41. It also includes an uplink receiver 43 designed to receive signals arriving from the mobile devices that are to be located (such as RACH bursts), and a downlink receiver 44 designed to receive signals arriving

from a BTS (such as BCCH signals). A communication link 46 that interfaces the LMU 40A with a remote MLC (not shown) is also provided. Preferably, the operation of the LMU 40A is controlled by a controller 45.

5 Signals arriving from both mobile devices and BTSs are picked up by the antennas 41, and received by the appropriate receiver 43 (for mobile device signals) and 44 (for base station signals). The uplink receiver 43 and downlink receiver 44 cooperate with the controller 45 to
10 note the time of arrival of the respective arriving signals. Recognizing when a signal has arrived at the uplink receiver 43 from a mobile device may be accomplished using conventional uplink control techniques. Similarly, recognizing when a signal has arrived at the downlink
15 receiver 44 from a BTS may be accomplished using conventional downlink control techniques. Optionally, the controller 45 may rely on digital signal processing (DSP) to implement these control functions.

20 Once a TOA for each arriving signal has been determined, the controller 45 forwards the determined TOAs to a remote mobile location center (MLC) via communication link 46. This communication link 46 may be implemented using any suitable technique including, for example, wired interfaces (e.g., over standard telephone lines) as well as
25 wireless interfaces (e.g., over the same network being used to communicate with the mobile device).

 In uplink mode, the TOA measurements made by the system must be aligned with respect to a common frame of reference in order for the MLC to form an accurate location

estimate. A convenient way of providing such a common
frame of reference is to incorporate a global positioning
satellites (GPS) receiver 47 in each LMU 40A, and to
reference each TOA measurement reported to the MLC with
5 respect to a received GPS time.

FIG. 4B is a schematic illustration of another dual-
mode uplink/downlink LMU 40B that may be used as any of the
LMUs 35-37 in the FIG. 3 embodiment. This LMU 40B enables
the FIG. 3 embodiment to locate handsets that communicate
10 using different wireless communication protocols (such as
ANSI-136 TDMA, GSM, AMPS, etc.), instead of being limited
to a single communication protocol. The LMU 40B is similar
to the LMU 40A (shown in FIG. 4A), except that the LMU 40B
includes a plurality of uplink receivers 43A-43C, a
5 plurality of downlink receivers 44A-44C, and a plurality of
communication links 46A-46C (instead of one uplink
receiver, one downlink receiver, and one communication
link). Preferably, each of the uplink receivers 43A-43C is
dedicated to a particular wireless communication protocol,
20 and each of the downlink receivers 44A-44C is dedicated to
a particular wireless communication protocol. Of course,
while three uplink receivers and three downlink receivers
are illustrated, a different number of receivers may be
substituted to accommodate any number of different wireless
25 communication protocols.

Preferably, each of the receivers 43A-43C, 44A-44C is
implemented on an individual circuit card that can be
plugged into a common backplane, and can be operated under
control of a common controller 45. This arrangement lets

each LMU operate for as many different wireless communication protocols as desired by plugging in additional receivers. Optionally, a separate communication link 46A-46C may be included for each wireless communication protocol. When separate communication links are provided, the same wireless network used to communicate with each handset can be used to forward the TOA measurements for that communication protocol to a remote MLC (e.g. an AMPS communication link for an AMPS handset, and a GSM communication link for a GSM handset). A separate MLC for each protocol may then be used to implement the location algorithms. When a single communication link is used for all the different communication protocols, a separate MLC may be used for each protocol, or a common MLC may be used for two or more communication protocols.

This arrangement, in which an LMU can make TOA measurements for different communication protocols, can be extended to uplink-only systems and downlink-only systems. For uplink-only systems, the block diagram would resemble FIG. 4B, but the downlink receivers 44A-44C would be omitted. For downlink-only systems, the block diagram would resemble FIG. 4B, but the uplink receivers 43A-43C would be omitted. Suitable modifications to the controller should also be made so that the controller does not expect TOA measurements from a non-existent source.

FIG. 5A is a schematic illustration of another dual-mode uplink/downlink LMU 50A that may be used as any of the LMUs 35-37 in the FIG. 3 embodiment. This LMU 50A includes

an antenna interface 52, which interfaces with one or more receiving antennas 51, and a combination uplink/downlink receiver 53 designed to receive signals arriving from the mobile devices that are to be located (such as RACH bursts) as well as signals arriving from a BTS (such as BCCH signals). A communication link 56 that interfaces the LMU 50A with a remote MLC (not shown) and an optional GPS receiver 57 are also provided. Preferably, the operation of the LMU 50A is controlled by a controller 55. Operation of the FIG. 5A embodiment is similar to the operation of the FIG. 4A embodiment described above, except that a single uplink/downlink receiver 53 is used in place of discrete uplink and downlink receivers (43 and 44, shown in FIG. 4A).

FIG. 5B is a schematic illustration of another dual-mode uplink/downlink LMU 50B that may be used as any of the LMUs 35-37 in the FIG. 3 embodiment. This LMU 50B enables the FIG. 3 embodiment to locate handsets that communicate using different wireless communication protocols (such as TDMA, GSM, AMPS, etc.), instead of being limited to a single communication protocol. Operation of this LMU 50B is similar to the operation of the LMU 40B (shown in FIG. 4B), except that an integrated uplink/downlink receiver is used for each communication protocol instead of discrete uplink receivers and downlink receivers for each communication protocol.

Implementing both downlink and uplink algorithms in a single system enables the system to take advantage of the benefits of downlink, while avoiding downlink's

shortcomings. More specifically, the dual mode location
uplink/downlink system described herein lets a system
operator add downlink handsets onto a communication network
without adding extra capacity to the network by locating
5 those handsets using the downlink mode. In addition, the
uplink/downlink system described herein can be used to
locate legacy handsets that do not support the downlink
mode. When a location estimate for one of these legacy
handsets is required, the system switches to the uplink
10 mode, and processes the signals arriving from the handsets
in order to determine the location of the handset. By
using the downlink mode as the default location mode, and
only switching to uplink mode for handsets that do not
support the downlink mode, the amount of new network
15 capacity that must be added can be kept to a minimum.
Preferably, new handsets that are added to the wireless
network will support the downlink mode in order to take
advantage of the benefits provided by downlink.

The most popular conventional location algorithms
20 operate by finding the intersection of two or more
hyperbolas, where each hyperbola is determined by a pair of
TOA measurements. In a single mode system, at least three
TOA measurements are needed in order to obtain two pairs of
TOA measurements (e.g., the pairs AB and AC can be formed
25 from three measurements A, B, and C). When only one pair
of TOA measurements is available in a single mode system, a
location estimate can not be formed.

When a dual mode system is available, however, a first
hyperbola can be obtained from a pair of TOA measurements

made using the uplink mode, and a second hyperbola can be obtained from a pair of TOA measurements made using the downlink mode. The intersection of these two hyperbolas can then be used as the estimate of the location of the mobile device. This is illustrated in FIG. 6, where a first hyperbola 68 is obtained using the uplink mode based on the TOA measurements of the signal from a handset 60 arriving at each of the LMUs 65, 66. A second hyperbola 69 is obtained using the downlink mode based on the TOA measurements of the signals from the BTSSs 61, 62 arriving at the handset 60, and the TOA* measurements of the signals from the BTSSs 61, 62 arriving each of the LMUs 65, 66. The intersection of the hyperbolas 68, 69 is used as the location estimate. Providing a location estimate based on an uplink hyperbola 68 and a downlink hyperbola 69 could make the difference between obtaining an accurate location estimate and not obtaining one, when two hyperbolas cannot be obtained using a single link direction. Moreover, even when two hyperbolas are available from a single link direction (i.e., either uplink or downlink), the additional hyperbolas obtained by relying on both technologies simultaneously can be used to improve the accuracy of the resulting location estimate.

Providing a dual mode uplink/downlink location system in accordance with the above-described embodiments may also reduce infighting between the various players in the wireless industry by supporting both location architectures simultaneously. It can also help make location services available to the public more rapidly by insuring that

investments in infrastructure for either technology will not be wasted.

Moreover, by combining multiple communication technologies in a single box, the number of new antenna sites needed to implement location services can be minimized. This arrangement should therefore minimize communities' resistance to the installation of the required infrastructure.

While the present invention has been explained in the context of the preferred embodiments described above, it is to be understood that various changes may be made to those embodiments, and various equivalents may be substituted, without departing from the spirit or scope of the invention, as will be apparent to persons skilled in the relevant art.

WE CLAIM:

1. A method of locating mobile devices, the method comprising the steps of:

(a) locating a first mobile device by implementing the steps of

(a1) determining times of arrival of a signal that originated from the first mobile device at each of at least three measurement units, and

(a2) computing a location of the first mobile device based on the times of arrival determined in step (a1); and

(b) locating a second mobile device by implementing the steps of

(b1) determining times of arrival of signals that originated from each of at least three base stations at the second mobile device,

(b2) determining times of arrival of the signals that originated from each of the at least three base stations at the measurement units, and

(b3) computing a location of the second mobile device based on the times of arrival determined in step (b1) and the times of arrival determined in step (b2).

2. The method of claim 1, wherein the second mobile device is capable of operating in a downlink mode, and the first mobile device is not capable of operating in a downlink mode.

3. A method of locating a mobile device, the method comprising the steps of:

(a) determining times of arrival of a signal that originated from the mobile device at each of at least two measurement units;

(b) determining times of arrival of signals that originated from each of at least two base stations at the mobile device;

(c) determining times of arrival of the signals that originated from each of the at least two base stations at the measurement units; and

(d) computing a location of the mobile device based on the times of arrival determined in the steps (a), (b), and (c).

4. The method of claim 3, wherein the computing step comprises the steps of:

defining a first hyperbola based on the times of arrival determined in step (a);

defining a second hyperbola based on the times of arrival determined in steps (b) and (c); and

locating an intersection of the first hyperbola and the second hyperbola.

5. A system for determining the location of a mobile device in either an uplink mode or a downlink mode, the system comprising:

an uplink processor that implements an uplink location algorithm;

a downlink processor that implements a downlink location algorithm;

at least three base stations, located at a known locations, that can communicate with the mobile device; and
at least three measurement units,

wherein, in the uplink mode, (a) each of the measurement units determines a time of arrival of a signal that originated from the mobile device and reports the determined time of arrival to the uplink processor, and (b) the uplink processor determines the location of the mobile device using the uplink location algorithm based on the times of arrival reported to the uplink processor by the measurement units, and

wherein, in the downlink mode, (a) the mobile device determines times of arrival of signals arriving from each of the at least three base stations and reports the determined times of arrival to the downlink processor, (b) the measurement units collectively determine a time of arrival of signals that originated from each of the at least three base stations and report the determined times of arrival to the downlink processor, and (c) the downlink processor determines the location of the mobile device using the downlink location algorithm based on the times of arrival reported to the downlink processor by the mobile device and by the measurement units.

6. The system of claim 5, wherein the uplink processor and the downlink processor are implemented in an integrated device.

7. The system of claim 5, wherein the uplink processor and the downlink processor are implemented in discrete devices.

8. The system of claim 5, wherein each of the measurement units includes a dual mode uplink/downlink receiver.

9. The system of claim 5, wherein each of the measurement units includes an uplink receiver and a downlink receiver that is distinct from the uplink receiver.

10. The system of claim 5, wherein each of the measurement units determines times of arrival for at least two different communication protocols.

11. The system of claim 10, wherein the at least two different communication protocols includes time division multiple access (TDMA) and global system for mobile communication (GSM) systems.

12. An apparatus for use in a communication system that includes a mobile device, a plurality of base stations located at a known locations, an uplink processor, and a downlink processor, the apparatus comprising:

a receiver that (a) notes a time of arrival of a first signal arriving from the mobile device, and forwards the noted time of arrival of the first signal to the uplink processor, and (b) notes a time of arrival of a second

signal arriving from the base station, and forwards the noted time of arrival of the second signal to the downlink processor.

13. The apparatus of claim 12, wherein the receiver comprises a first receiver that notes the time of arrival of the first signal and a second receiver that notes the time of arrival of the second signal, and wherein the first receiver is physically discrete from the second receiver.

14. The apparatus of claim 12, wherein the receiver comprises a first receiver that notes the time of arrival of the first signal and a second receiver that notes the time of arrival of the second signal, and wherein the first receiver is integrated together with the second receiver.

15. The apparatus of claim 12, wherein the first signal comprises a random access channel (RACH) signal, and the second signal comprises a broadcast control channel (BCCH) signal.

16. The apparatus of claim 12, wherein the receiver determines times of arrival for at least two different communication protocols.

17. The apparatus of claim 16, wherein the at least two different communication protocols includes time division multiple access (TDMA) and global system for mobile communication (GSM) systems.

ABSTRACT OF THE DISCLOSURE

Certain aspects of the disclosure relate to combining uplink and downlink location technologies into a single location-service system, to obtain the benefits offered by both of technologies while eliminating many of their individual shortcomings. Mobile devices that support downlink can then be located using the downlink mode, and mobile devices that do not support downlink can be located using the uplink mode. A mobile device may even be located based on a combination of uplink measurements and downlink measurements. Other aspects of the disclosure relate to providing a single location-service system to locate mobile devices that communicate using a plurality of different communication protocols.

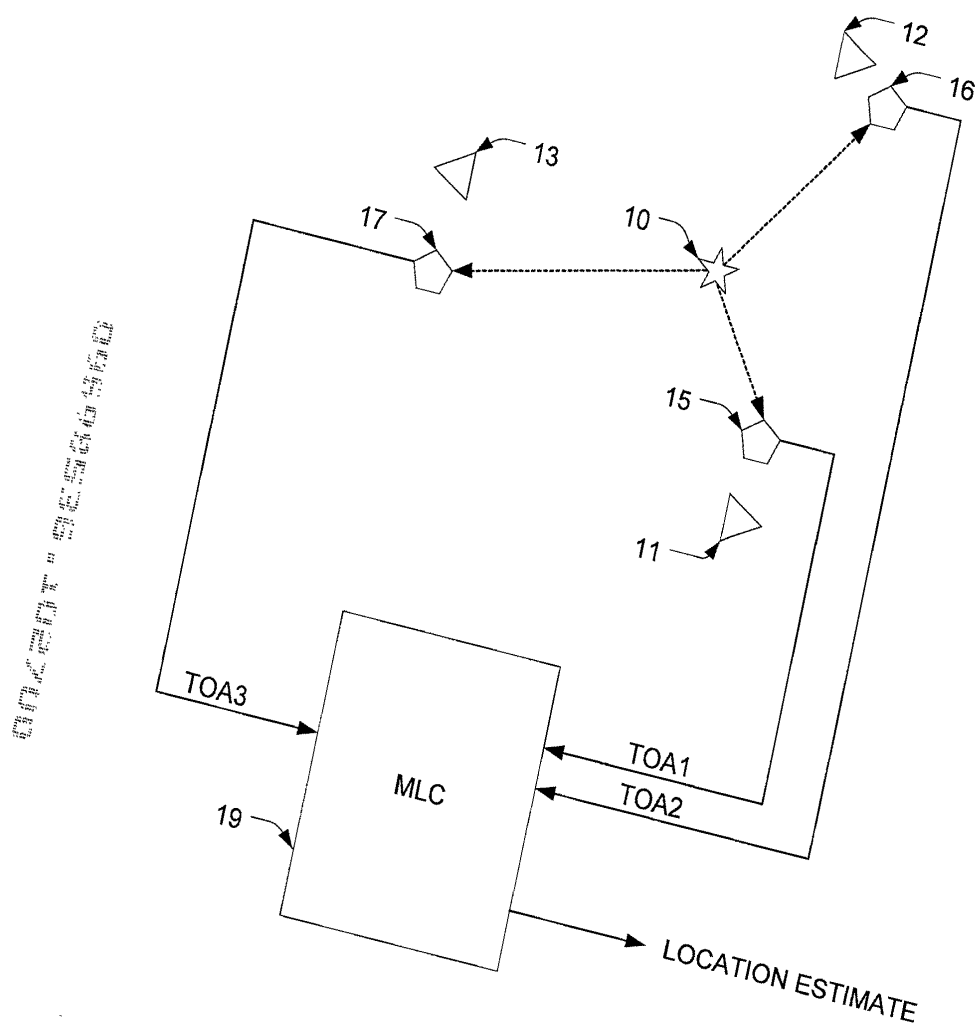


FIG. 1
PRIOR ART

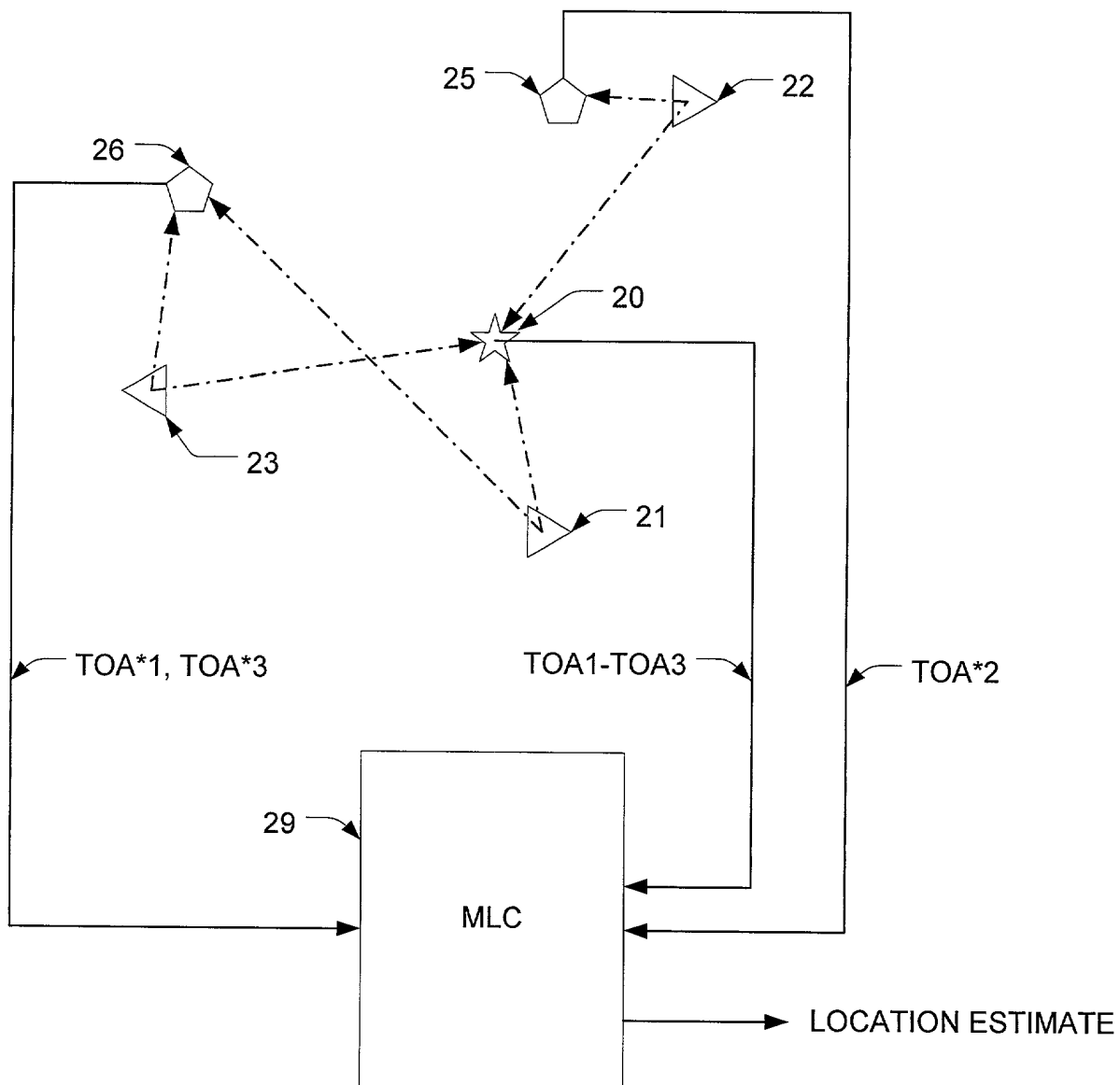
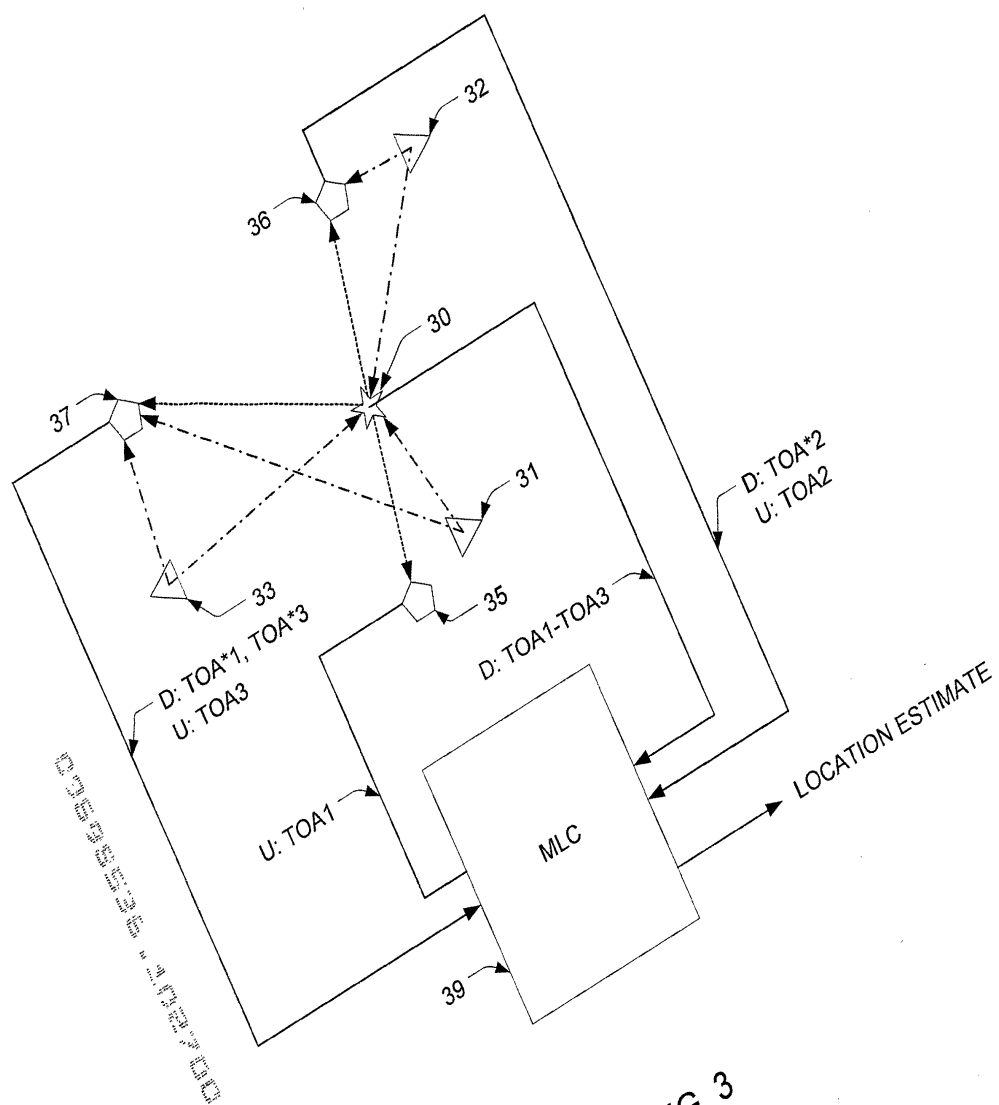


FIG. 2
PRIOR ART



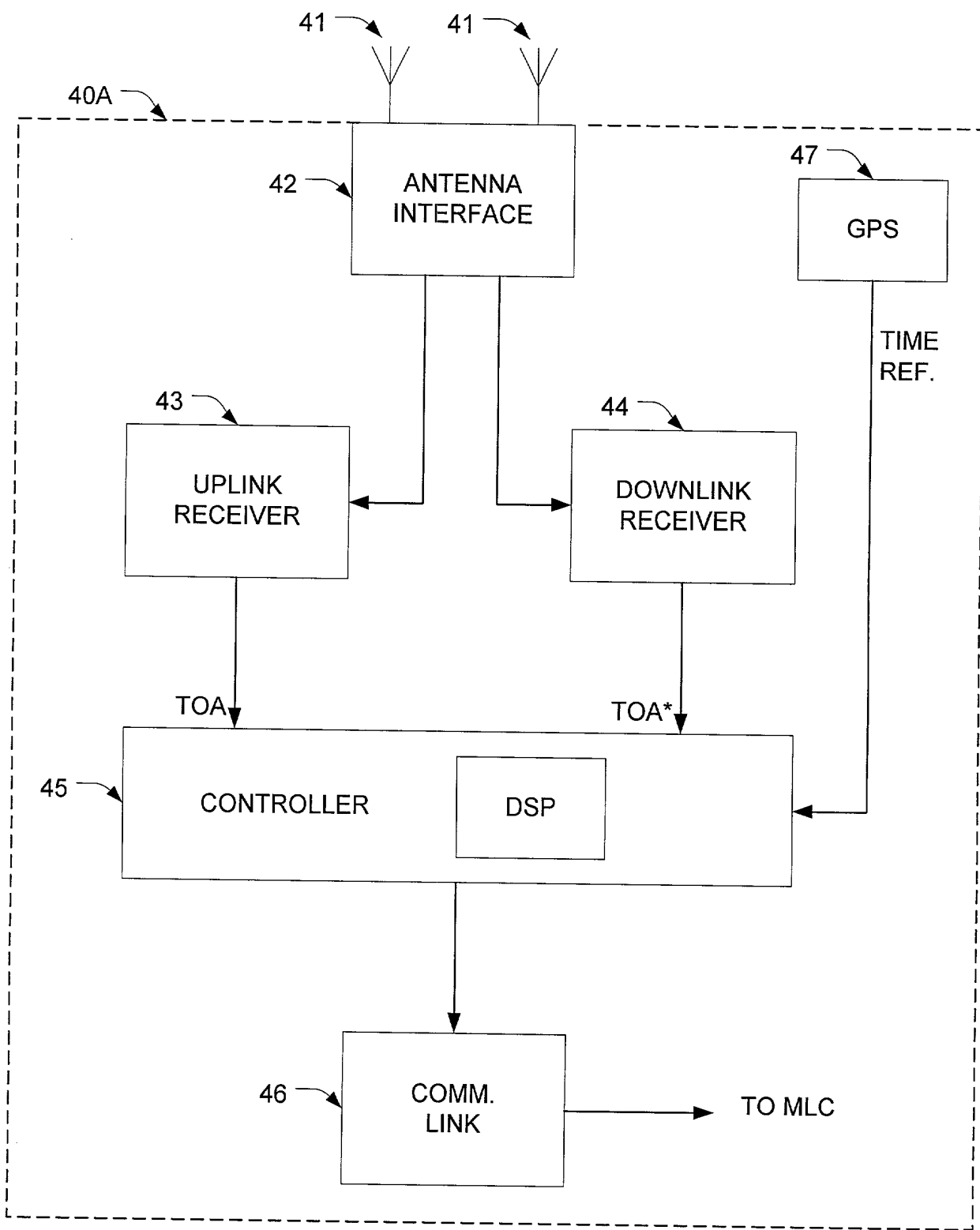


FIG. 4A

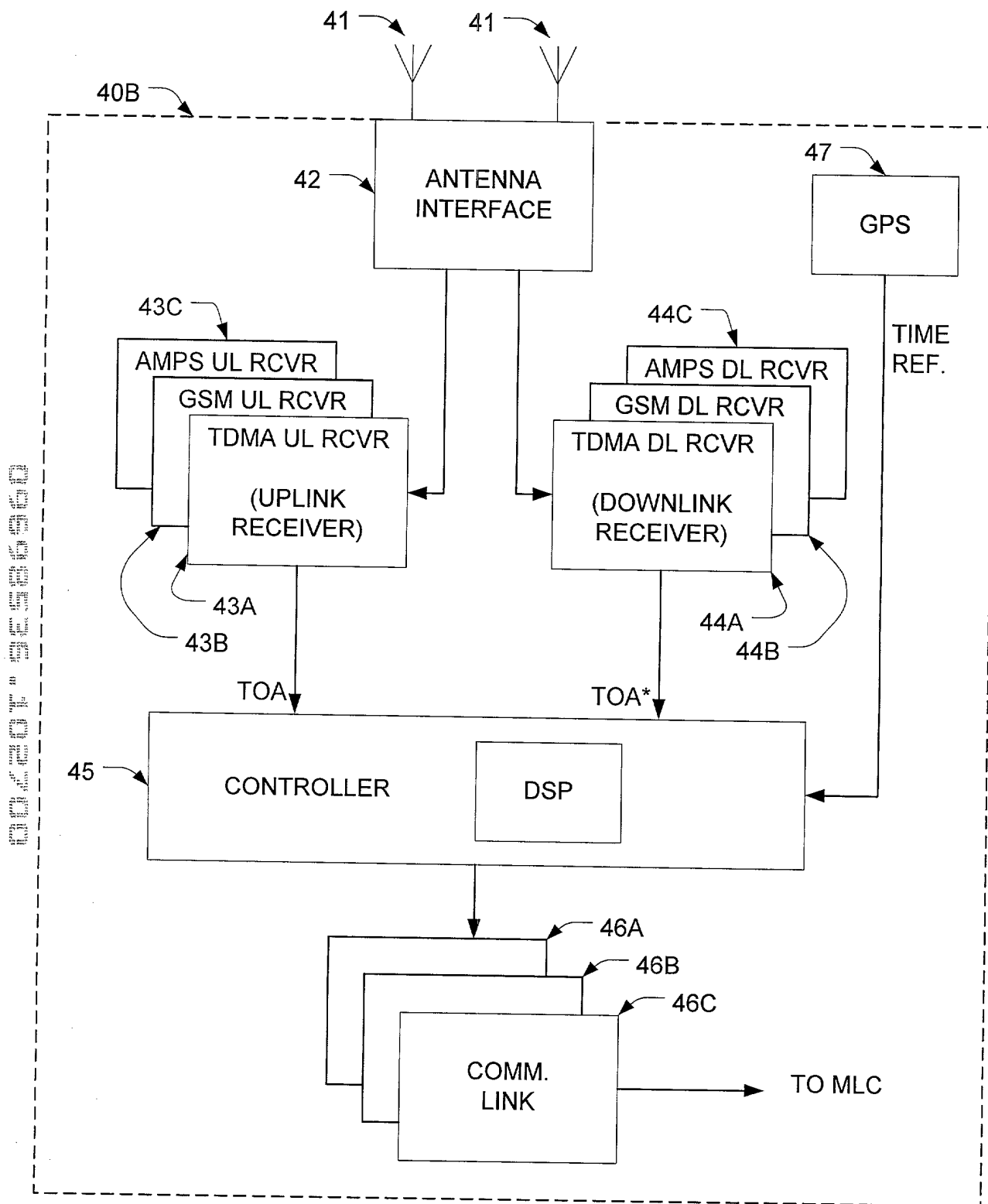


FIG. 4B

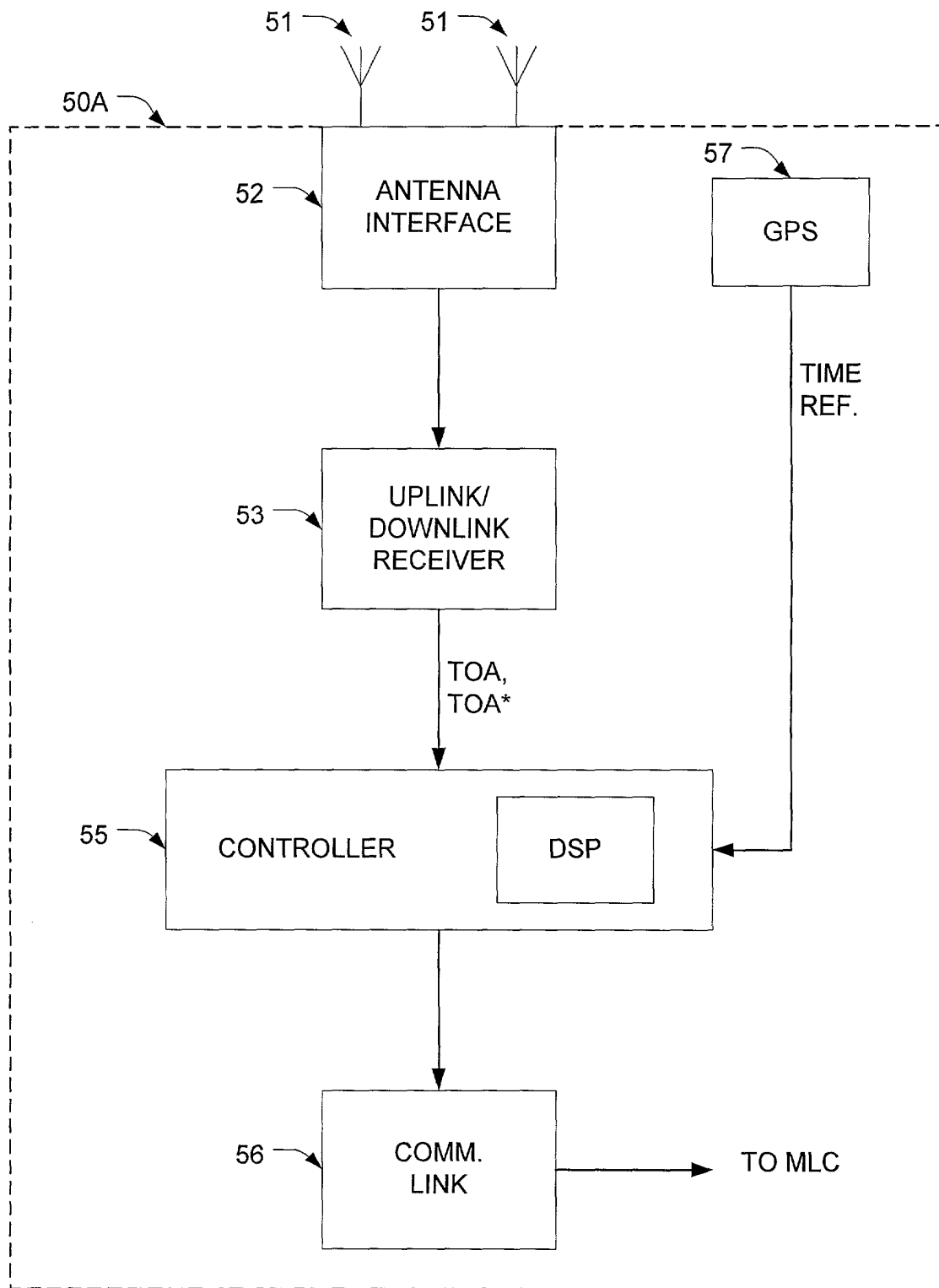


FIG. 5A

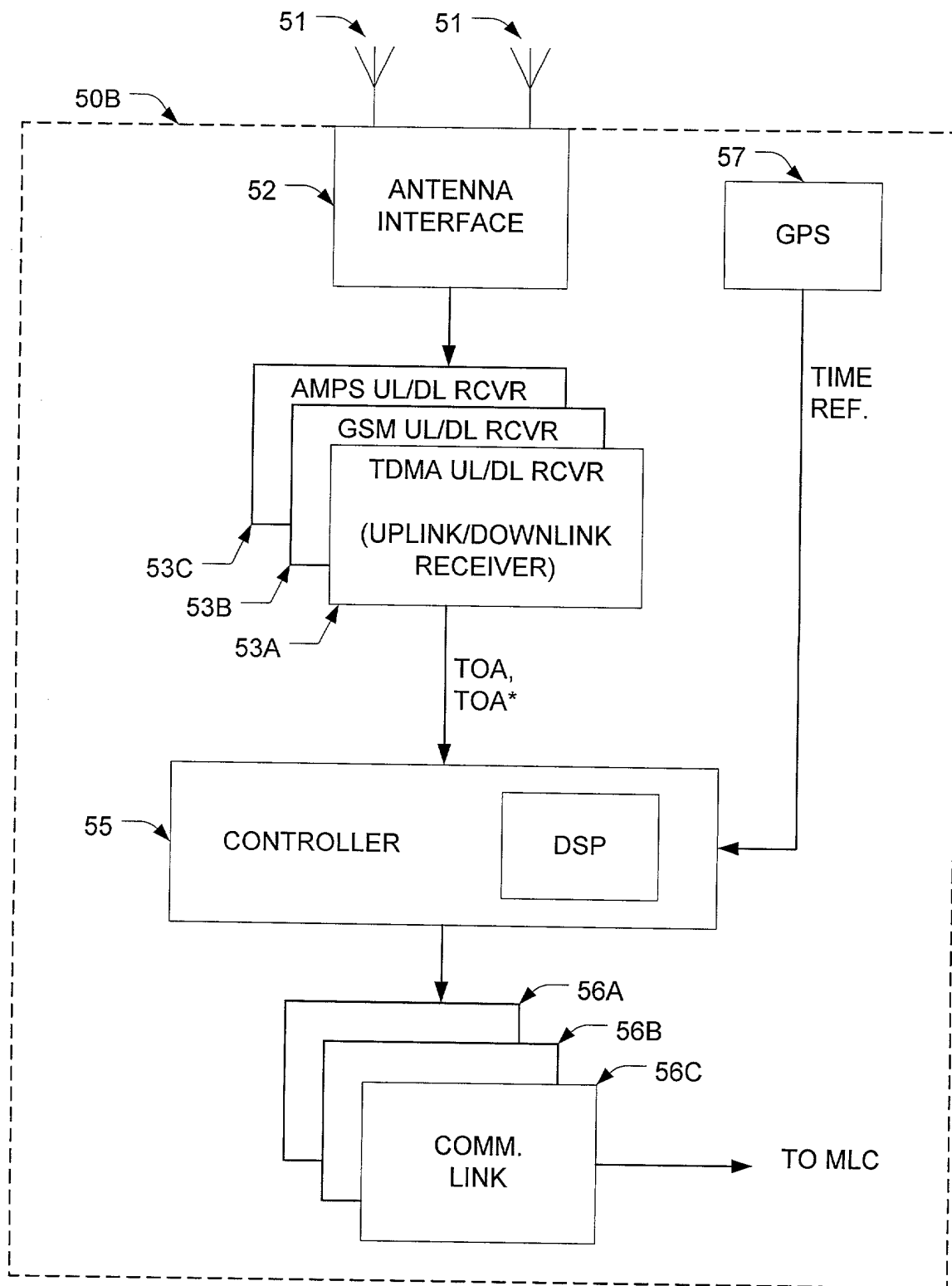
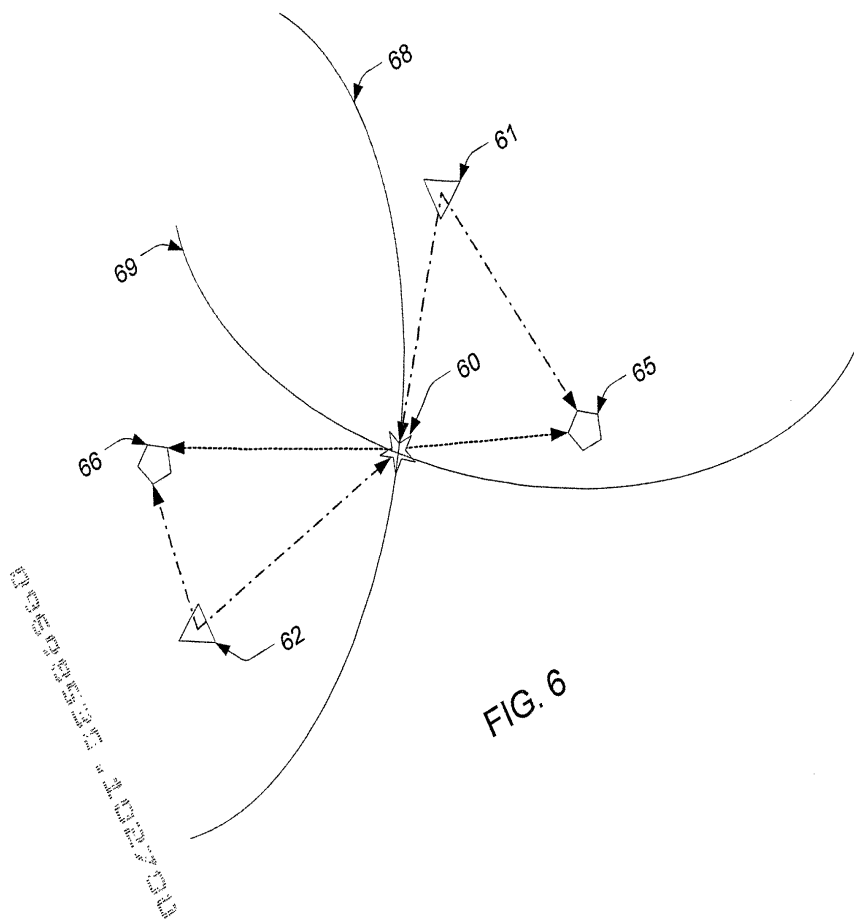


FIG. 5B



**UTILITY DECLARATION
AND POWER OF ATTORNEY**
Utility Application

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled DUAL MODE UPLINK/DOWNLINK LOCATION MEASUREMENT AND MULTI-PROTOCOL LOCATION MEASUREMENT, the specification of which

(Check One) ☒ is attached hereto OR
☐ was filed on _____ as United States Application Serial No. SerialNumber or PCT International Application No. _____ and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment(s) referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, § 1.56.

POWER OF ATTORNEY: As a named inventor, I hereby appoint as my attorneys and/or agents, with full power of substitution and revocation, to prosecute this application and transact all business in the United States Patent and Trademark Office, and in countries other than the United States, and to do all things necessary or appropriate therefor before any competent International Authorities in connection with any international patent application(s) corresponding to the above-identified invention application, all of the registered practitioners identified by Customer Number 22249:



22249

PATENT TRADEMARK OFFICE

LYON & LYON LLP
Suite 4700
633 W. Fifth Street
Los Angeles, CA 90071
(213) 489-1600

Please send all correspondence to the attention of Robert S. Mayer, Esq., and direct all telephone calls to **914-421-4609**.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Title 18, United States Code, § 1001 and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

201	FULL NAME OF INVENTOR	FIRST Name Gregory	MIDDLE Initial G.	LAST Name Davis	
	RESIDENCE & CITIZENSHIP	City Monument	State or Foreign Country Colorado	Country of Citizenship United States	
	POST OFFICE ADDRESS	1095 Lake Woodmoor Drive	City Monument	State or Country Colorado	Zip Code 80312
INVENTOR'S SIGNATURE				DATE <u>9/25/00</u>	

202	FULL NAME OF INVENTOR	FIRST Name Richard	MIDDLE Initial C.	LAST Name Stribling	
	RESIDENCE & CITIZENSHIP	City Colorado Springs	State or Foreign Country Colorado	Country of Citizenship United States	
	POST OFFICE ADDRESS	2957 Shrider Road	City Colorado Springs	State or Country Colorado	Zip Code 80920
INVENTOR'S SIGNATURE <u><i>Richard Stribling</i></u>			DATE <u>9/26/00</u>		

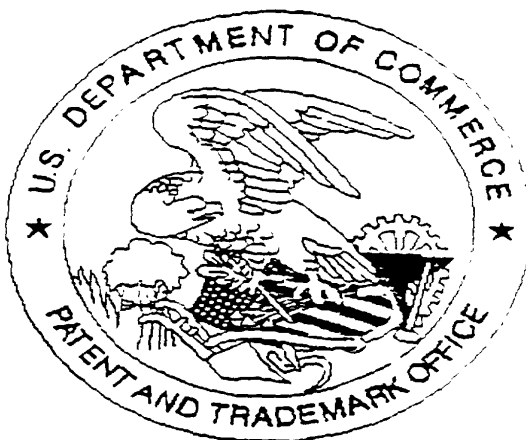
203	FULL NAME OF INVENTOR	FIRST Name Randy	MIDDLE Initial L.	LAST Name Engle	
	RESIDENCE & CITIZENSHIP	City Colorado Springs	State or Foreign Country Colorado	Country of Citizenship United States	
	POST OFFICE ADDRESS	899 Tari Drive	City Colorado Springs	State or Country Colorado	Zip Code 80921
INVENTOR'S SIGNATURE <u><i>Randy L Engle</i></u>			DATE <u>9/26/00</u>		

204	FULL NAME OF INVENTOR	FIRST Name Richard	MIDDLE Initial M.	LAST Name Nelhams	
	RESIDENCE & CITIZENSHIP	City Monument	State or Foreign Country Colorado	Country of Citizenship United Kingdom	
	POST OFFICE ADDRESS	19920 Silver Horn Lane	City Monument	State or Country Colorado	Zip Code 80132
INVENTOR'S SIGNATURE <u><i>R. Nelham</i></u>			DATE <u>10/24/00</u>		

205	FULL NAME OF INVENTOR	FIRST Name	MIDDLE Initial	LAST Name	
	RESIDENCE & CITIZENSHIP	City	State or Foreign Country	Country of Citizenship	
	POST OFFICE ADDRESS		City	State or Country	Zip Code
INVENTOR'S SIGNATURE _____			DATE _____		

206	FULL NAME OF INVENTOR	FIRST Name	MIDDLE Initial	LAST Name	
	RESIDENCE & CITIZENSHIP	City	State or Foreign Country	Country of Citizenship	
	POST OFFICE ADDRESS		City	State or Country	Zip Code
INVENTOR'S SIGNATURE _____			DATE _____		

United States Patent & Trademark Office
Office of Initial Patent Examination -- Scanning Division



SCANNED, # 12

Application deficiencies were found during scanning:

☐ Page(s) _____ of _____ were not present:
for scanning. (Document title)

☐ Page(s) _____ of _____ were not present:
for scanning. (Document title)

☒ Scanned copy is best available. *Drawings*

Figs 1, 3, and 6 skewed drawings
